METEOROLOGICAL AND CLIMATOLOGICAL SITING CRITERIA FOR AN INTERNATIONAL RADIONUCLIDE MONITORING SYSTEM

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1. <u>Introduction</u>

In response to the Comprehensive Test Ban Treaty negotiations, it has been proposed (Mason, 1995) to deploy a Global Atmospheric Radionuclide Detection System (GARDS) to detect, identify, and locate potential nuclear weapons tests. Careful consideration to the placement of the high purity germanium detectors, which are to be deployed globally, is required, so as to minimize false readings and maximize the detection ability of the instrument.

This paper will present meteorological criteria to be considered when defining deployment locations. Such criteria will be centered on the influence of the surrounding terrain on the local meteorology in section 2, and how it may impact the ability of the measurement device to detect a passing debris cloud. Many of the criteria come from experience with siting precipitation chemistry samplers in the United States and Canada. It should be noted that these are only general guidelines, and that a detailed study of the local terrain and its effects on the local meteorology should be performed to accurately know the impact on plume sampling. Also, it is assumed that a single measurement site will not detect nuclear material until it has travelled for two to three days, and therefore, the problem is on a regional scale (100's to 1000's of kilometers). This assumption eliminates the terrain effects on the initial characteristics of the plume, very near the source location, which can be very complex and has been addressed with both modeling and measurement studies elsewhere.

In section 3, the effect of major population centers on the transport of pollutants is provided, and in section 4, the requirements for supporting meteorological measurements near the sampling location are detailed. In section 5, mesoscale modeling is introduced as a means of assessing the local climatology, and whether or not an area can be considered a viable site location. Finally, in section 6, a summary of meteorological siting criteria are presented.

2. <u>Terrain</u>

The influence of terrain on atmospheric flow, and therefore, the dispersion of atmospheric contaminants, has been well documented (Peagle, *et al.*, 1990; Venkatram, 1988). Fortunately, most of the influences are local (within 100 km) and should not impact, to a large extent, the ability of a sampler to detect a debris cloud that has traveled for several days, since the cloud will be well mixed within the lower portions of the atmosphere. However, there are several terrain criteria that could impact the larger scale detection capability due to vertical stratification and should be addressed when locating a sampler:

2.1. Locate in fairly flat terrain

Whenever possible, the sampler should be located in fairly flat terrain (Bigelow, 1984) and preferably on top of a small rise in the terrain. Obstructions, such as buildings and trees, should be at a distance from the sampler of at least 4 times the height of the obstruction (Vet *et al.*, 1986). However, if possible, this distance should be increased up to 10 times the height of the obsruction. The surrounding vegetation should be low cut grasses (Vet *et al.*, 1986) if possible, so as to minimize its influence on the wind flow.

2.2. Locate upwind of large terrain features

If the sampler must be placed near complex terrain, it should be located upwind (in the direction of the mean wind flow) of large terrain features. Wind flow over high mountains tends to rain-out pollutants on the windward side, and therefore a measurement site on the leeward side may miss the bulk of the nuclear material. In addition, the nuclear material that is wet-deposited on the ground will be resuspended into the air after evaporation, and therefore, if the material was undetected when first passing over the sampler, it may be able to detect the resuspended material.

2.3. Effect of nocturnal temperature inversions and daytime mixing

The sampler should not be placed in deep mountain valleys. Temperature inversions (temperature increasing with height) may form in river valleys and mountain passes at night and during the winter months, and inhibit the mixing of the atmosphere near the ground. The top of the inversion layer can vary depending on the terrain and time of year, but is generally around 500 m. The inversion will separate the lower atmosphere into distinct flow regimes and can trap pollutants either above or below the inversion. Therefore, if a sampler is located in a valley, it can be cut off from the nuclear material passing overhead, above the nighttime inversion. During the daytime, the lower portions of the atmosphere become unstable with the heating of the ground. This heating causes the well-mixed layer to rise to several kilometers by midday, while at the same time mixing down pollutants previously above the nighttime inversion. Therefore, if a sampler is to be placed near complex terrain, it should be placed above the nighttime inversion, and below the top of the daytime mixed layer, to maximize the chances of detecting the transport of nuclear material. The heights of the nighttime inversion and daytime mixed layer vary by location and will need to be determined before siting the sampler.

2.4. Locate away from large water bodies

Large water bodies can produce very complex flow regimes up to 50 km from the shoreline because of the temperature differences between the water and the surrounding terrain. Lake- and sea-breeze flows are examples of types of circulations that can form near the shoreline. Although these flows may be well within large-scale pollutant plumes and hence, may have a marginal effect on the sampling, meteorological back-trajectories can be additionally complex in these situations. Therefore, samplers should be located at least 10 km from large lakes and 50 km from salt-water bodies (Vet *et al.*, 1986) so as to minimize their influence on the flow conditions around the sampling site.

3. Population Centers

The local meteorology can also be influenced by large population centers. Cities can create a "heat island" effect due to it's ability to absorb heat in structures and pavement. The heat island creates mesoscale flows by acting like a solid structure and causing the flow to go around the city. Therefore, placement near large cities should be avoided when trying to sample the regional scale flow. The following criteria should be followed:

3.1. Locate away from population centers

The sampler should be located at least 10 km (20 km) distant from populations centers of less than 75,000 (more than 75,0000) people, or at least 20 km (40 km) distant if the population center is located upwind (mean annual wind direction) of the sampler (Bigelow, 1984; Vet *et al.*, 1986).

4. Meteorological Measurements

Since the goal of the measurement network is to locate sources of nuclear tests, it is very important that good quality meteorological measurements are available.

Dispersion models that will be used to trace back the nuclear material to it's source, require detailed information on the wind flow between the source and the sampler. Therefore, the following criteria should be followed:

4.1. Wind, precipitation and temperature

If possible, a measurement of surface wind direction and wind speed, precipitation amount, as well as surface air temperature for stability information, should be made at the sampler location and be available in real-time to the modelers. Precipitation measurements may prove to be helpful in determining any atmospheric wet deposition of radioactive material, i.e., airborne material that may have resulted from resuspension.

4.2. National meteorological network data

The sampler should be located as near as possible to a source of surface and upper-air weather information from a national meteorological service. These data are available world-wide, and are used in global meteorological forecast models, which in turn, drive the dispersion models used to track nuclear material.

5. Use of mesoscale atmospheric models to create local-area climatologies

Local and mesoscale meteorological patterns can have an important effect on a region's climate. In the coastal zone, for example, local-scale atmospheric conditions are often controlled by thermally induced circulations forced by land-water contrasts. Studies over South Florida have shown that mesoscale sea breeze circulations are the dominant weather condition for 30 % of the year. Mesoscale processes can also control typical flow patterns in complex terrain areas. Unfortunately most surface observational networks are not adequate to characterize the mesoscale climatology of an area. Mesoscale atmospheric models can therefore be used to supplement the gaps in the observations and incorporate any local-scale terrain-induced features.

Since the 1970's, numerical models have been developed and applied to resolve and simulate mesoscale atmospheric circulations. These models normally are based upon solving the prognostic fluid dynamic equations in a Eulerian framework for momentum, temperature, atmospheric moisture and pressure. Recently sophisticated parameterizations of the atmospheric boundary layer and the effects of vegetation and soils, clouds, radiations and precipitation processes have been included in these models. These mesoscale processes have been shown (Pielke, *et al.* 1991, Avissar and Pielke, 1989) to have a significant effect on local climate and should be parameterized or explicitly modeled when attempting to create a mesoscale climatology.

Previous attempts have been made to develop mesoscale climatologies for an area using numerical models (Pielke, 1988; Lyons and Fisher, 1988; Lyons, *et al.*, 1992a) and by combining model results with satellite observations (Michaels, *et al.*, 1987; McQueen and Pielke, 1985) and with radar data (Blanchard and Lopez, 1985).

The Regional Atmospheric Modeling System (RAMS, Pielke *et al.*, 1992) has been used at the National Oceanic and Atmospheric Administration's (NOAA) Air Resources Laboratory (ARL) with four-dimensional data assimilation to simulate mesoscale meteorological processes, and can be used to identify mesoscale circulations around a potential receptor point. The fine-scale model winds can also be used to refine back trajectories calculated using synoptic-scale model fields. Model resolutions of 2 km or less may be required to simulate the significant local-scale processes in even less complex terrain, such as around the Susquehanna, PA nuclear power plant (McQueen, *et al.*, 1995), and around Cape Kennedy (Lyons, *et al.*, 1992b). Since such fine-scale resolutions may be required, RAMS could be run for certain pre-determined cases, which would typify several synoptic regimes around the site. The trajectory clustering technique of Stunder (1995) can also be used to determine typical flow regimes. RAMS can then be run for these regimes to determine the typical mesoscale flows. From the RAMS simulations, and the ARL synoptic archives, typical back-trajectories or dispersion patterns from a source can be created to determine which receptor site has the highest probability to measure pollutants from a particular source region.

5. Summary

Meteorological siting criteria for nuclear measurement samplers is dependent on the local terrain. Criteria presented here are very general in nature, and should not be used without a detailed examination of the local topography and its effect on the wind flow surrounding the chosen site location. The following summarizes the criteria mentioned above:

- <u>Terrain</u>

  Locate

  · on a small rise in otherwise fairly flat terrain.

  · at a distance of at least 10 times the height of any obstructions, such as buildings and trees.

  · with surrounding vegetation of low cut grasses.

  · upwind of large terrain features.

  · away from river and mountain valleys.

  · at least 10 km from large lakes and 50 km from salt-water bodies.

- <u>Meteorological Measurements</u>

  · Co-locate with measurements of surface wind speed, wind direction, precipitation amount and surface air temperature.

  · Locate near a source of surface and upper-air weather information from a national meteorological service.

- <u>Population Centers</u>

  · Locate > 10 km for < 75,000 people (> 20 km if upwind).
  · Locate > 20 km for > 75,000 people (> 40 km if upwind).

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